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# THE POTENTIAL OF WASTE-BASED RENEWABLE ENERGY WITH A GAS LANDFILL SYSTEM IN PALOPO

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**ABSTRACT**

*The government encourages the development of waste management by utilizing waste as a new renewable energy source through waste to energy technology as an effort to overcome the increasing volume of waste and the dependence of electricity production from new coal mineral resources. This study aims to explain how much waste-based renewable energy potential in Palopo can produce through landfill gas. The research method uses the LandGem-v302 tool to calculate landfill gas production, calculate the economic feasibility value using the investment criteria net present value, internal rate of return, benefit cost ratio and payback period. The results of the LandGem-v302 test with projected data for 2024-2030 show that the volume of waste at the Mancani landfill has the potential to produce landfill gas and methane gas to produce renewable energy for approximately 80 years of production from 2025-2110. The economic value feasibility test also shows that the economic value of waste based EBT can be categorized as feasible. Thus, the projection of waste in Palopo City in 2024-2030 has the potential to produce renewable energy and is worth investing in for long-term development in Palopo.*

**KEYWORDS** *waste; landfill gass; landGEM; waste to energy; renewable energy*



## INTRODUCTION

The waste problem in Indonesia is still a complicated polemic to this day. It is certain that the amount and type of waste will continue to be generated and will tend to increase every year, given the growth in population and public consumption which also continues to increase (Thoengsal & Tumpu, 2022). Meanwhile, waste management solutions and are still far behind. In 2021, the total national waste

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production will be 68.5 million tons and will increase to 70 million tons in 2022. As for waste management, there is 24% or 16 million tons of waste that has not been managed to date, only 7% is recycled and 69 % that goes to TPA (Final Disposal Site) (Commission IV, 2022).

The main problem with waste generation is that waste generation often exceeds the capacity limits of available processing and final disposal sites, resulting in accumulation of waste (Darmawan et al., 2020). So that an effective and efficient waste management system is needed to reduce waste. Garbage is the residue from household consumption activities, business entities, or factory activities. If not managed properly, waste will have a negative impact on the environment and health. So this garbage problem needs to be solved as soon as possible. Law No. 18 of 2008 Challenge of Waste Management explains that by carrying out environmentally sound waste management, we will receive benefits in addition to reducing the amount of waste volume, we will obtain other benefits such as economic benefits.

One of the negative impacts of waste on the environment is environmental pollution through water, air and soil. Maha & Susilawati, (2023) explained the level of environmental pollution is one of the determining factors for the level of people's life expectancy. So it is very important to maintain environmental quality standards. Efrizal, (2022) also explained that poor waste management is one of the causes of dioxin pollution. Dioxins can have a long-term impact causing cancer, reproductive disorders and can reduce children's learning abilities. The two studies show the bad impact of waste, so that management with an environmental perspective is needed.

Another thorny issue in the environmental field is the energy/electricity problem. Along with the growth of per-capita electricity consumption in 2020 it will reach 1.09 mWh (Central Bureau of Statistics, 2020). The activities of modern society are also increasingly dependent on technological facilities that require electrical power, the government is still very dependent on energy derived from coal resources, 60% of national energy needs come from fossil fuels and coal (esdm.go.id, 2020). Even though the Coal-fired Steam Power Plant (PLTU) causes many environmental problems to occur around the power plant area from an economic, social and health standpoint (Muttar et al., 2021).

Supriatna, (2021) explains at least there are two reasons why electrical energy from coal is also called dirty energy. First, coal mining activities are one of the causes of deforestation. Second, one of the causes of the climate crisis and air pollution, coal produces the highest CO2 pollutant compared to other resources. That way, the government needs to look for alternative sources of power as power plants, such as solar, wind, air, and several other energy sources (Surma et al., 2020).

The efforts made by the government to reduce electricity production from coal are the new renewable energy transition. The government is targeting to have New Renewable Energy (EBT) of 23% by 2025 (Ministry of Energy and Mineral Resources, 2023). The government's seriousness in the EBT energy transition can be seen by the issuance of several regulations related to EBT. One of the EBT that is being developed by the government is waste-based EBT, waste is managed using special technology to convert it into electrical energy (Waste to Energy) or commonly known as a Garbage Power Plant (PLTSa). Several regulations that support the development of EBT include Law no. 30 of 2007 concerning Energy which is the umbrella for the development of EBT. PP No. 79 of 2014 concerning the National Energy Policy (KEN) which states that waste is a renewable energy source, and the use of waste for energy is directed at electricity and transportation. While Law no. 18 of 2008 concerning waste management also regulates that waste can be used as an energy source, then to accelerate the development of waste management into electrical energy, Presidential Decree No. 35 as an umbrella for accelerating the development of installations for processing waste into electricity based on environmentally friendly technology.

Waste to energy (WtE) technology is a technology that can convert waste into new energy or electricity, in other words this technology utilizes it as the main fuel for producing electrical energy, this technology is usually called PLTSa (Qodriyatun, 2021). By implementing waste management with the PLTSa system, the amount of waste volume can be controlled and can produce renewable energy. One of the PLTSa technologies that has been widely developed is technology that utilizes landfill gas as fuel to drive generators and generate electricity, landfill gas is gas produced from the solid-state fermentation process in the landfill system, the main content of landfill gas to produce electrical energy is methane (Esye & Iswal, 2021).

Khrisna et al., (2022) explained waste potential at Kebun Congo TPA is feasible to be realized as PLTSa. This is based on the results of research using LandGEM software showing that the Congo plantation TPA has the potential to produce landfill gas (LFG) of 7,100,769.959 m3/year and is capable of producing up to 64,226,464.28 kWh/year of electricity. The results of the economic aspect test also show that the energy potential produced meets the NPV, PP, BCR, and IRR criteria. So it is feasible to invest in PLTSa landfill gas. In a similar study Shukri & Jelita (2023) also concludes that the potential for waste as a waste power plant with a landfill gas system is technically and economically feasible.

Even though research on the potential of waste-based EBT shows positive things, in practice PLTSa development is still constrained in several regions. Qodriyatun (2021) explains high tipping fee because the waste is not properly segregated, the local government budget is limited making it difficult to choose the appropriate technology for the existing waste, the low local government policy for waste management, the low human resources needed for PLTSa management, the high selling price of PLTSa electricity compared to electricity from coal and there are no incentives for PLTSa developers and it is difficult to find bank funding for PLTSa development are the reasons why PLTSa development is still constrained.

Palopo City is one of 3 Madya cities in South Sulawesi Province, its main economic sector is the service business and culinary business. Along with population growth and consumption patterns, the volume of waste also increases. From data National Waste Management Information System (2023) the total volume of waste in the city of Palopo increased from 33,704 tons in 2021 to 34,187.91 tons in 2022 with the amount of waste generation reaching 93.67 tons per day. With municipal status and cultural history, the city of Palopo is widely chosen as a weekend tour, so that conditions like this have the potential to increase the volume of waste production. Without environmentally sound waste management, waste in Palopo City will have a negative impact on the environment and public health. The area of the Mancani landfill is approximately 11 hectares, with conditions such as waste generation, the capacity of the Mancani landfill is in over capacity (Ishari, 2022).

Based on the background described above, researchers are interested in conducting research that aims to describe whether the waste in Palopo City has the potential to produce new renewable energy to support the national energy transition to clean energy. Apart from being aimed at adding to the literature on renewable energy, this research is also a researcher's endeavor to assist the process of accelerating the transition towards new, renewable energy.

## RESEARCH METHOD

### Landfill Gas Based Renewable Energy Potential

For a long time, waste has caused various problems for the environment and social life of the community. However, since the government has pushed for the development of environmentally sound waste management with the technology of converting waste to electricity (waste to energy), waste is now an advantage as the main raw material for new and renewable energy sources. The use of waste to energy (WtE) technology to convert waste into energy can replace fossil resources and coal which are decreasing in number. Nationally, waste can generate 49,810 MW of electricity. In 2015, power plants that were installed on-grid (connected to PLN) produced 91.1 MW, while those that were off-grid produced 1,626 MW (Romy et al., 2023).

Indonesia has a large waste potential, the amount is increasing every year nationally and even on a regional scale. This is influenced by the large population, the high rate of population growth and the high activity of public consumption. According to (Commission IV, 2022) in 2021 the volume of waste in Indonesia will reach 68.5 million tons and in 2022 it will increase to 70 million tons. For the city of Palopo, from SIPSN data, (2023) the amount of waste volume increased from 33,704 tons in 2021 to 34,187.91 tons in 2022 with the amount of waste generated per day reaching 93.67 tons. With the potential for a large amount of waste, the development of PLTSa in Indonesia is a solution to the problems caused by waste (Utoyo & Sudarti, 2022).

Converting waste into energy is an alternative solution for urban waste management. A study on waste and its energy potential for TPA Memelakha and TPA Pekarshing shows that until 2050, TPA Memelakha has the potential to generate power of 8.85 Megawatts (MW) and 1.44 Megawatts (MW) for Pekarshing. In terms of energy efficiency and percentage of waste, the gasification process is the most feasible method for WTE conversion at these two locations, with a reduction in the volume of waste in TPA by 80% to 90% (Choden et al., 2021).

Cudjoe et al., (2021) stated waste management with WTE technology has the potential to produce renewable energy in the cities of Beijing, Tianji, and Hebei. In addition, the energy produced also has economic value from the three cities. This shows that waste managed using WTE technology apart from having the potential to produce renewable energy can also provide economic value and most importantly the ability to reduce waste volume.

One of the inexpensive WTE technologies is gasification which utilizes methane gas as fuel to produce energy. Methane gas is a major component of landfill gas produced from the waste management process using the landfill system (control landfill & sanitary landfill). In addition to the potential to produce energy, the landfill system also provides economic value which is suitable for use in African countries. In addition, environmental impact analysis shows that an average landfill gas-to-electricity project can reduce global warming potential by 72.2% (Cudjoe & Han, 2021).

Kusuma et al., (2020) giving an explanation landfill gas or LFG is a gas produced by microorganisms when organic matter undergoes a fermentation process under anaerobic conditions that are suitable both in terms of temperature, humidity and acidity. LFG can be generated by the decomposition of organic matter in landfills. The gas produced by the landfill gas (LFG) is then captured by the gas well and assisted to be raised to the surface using a blower which aims to turn the turbine and generate electricity. Most of the gas content of landfills consists of methane and carbon dioxide (Huda et al., 2019).

Chand et al., (2020) mention there are several key steps in the collection, processing and final use of LFG such as: (1) Decomposition of waste in landfills, (2) LFG extraction wells and pipes, (3) Primary processing of LFG, (4) Additional treatment for quality improvement and (5) Use as a renewable energy source.

Chandra & Ganguly (2023) explained methane gas left alone in TPA is one of the biggest causes of greenhouse gas emissions. He added that by using methane gas to produce electricity, it will indirectly reduce greenhouse gas emissions.

Ramprasad et al. (2022) there are at least three main reasons why landfill gas must be managed with WTE technology. First, landfill gas is a major constituent of greenhouse gases and has the potential for energy production. Second, methane gas and carbon dioxide gas are always produced through the process of microorganisms in waste generation. Third, methane gas can be extracted and used as a sustainable alternative energy source.

**LandGem-v302**

Ramprasad et al. (2022) LandGEM-302 is a model developed by the United States Environmental Protection Agency (USEPA) to calculate the amount of landfill gas produced in landfills. adopted two important parameters for predicting GFR, namely first order methane production rate constant (kin per year) and methane production potential (Lo-in cu. m per Mg). One of the main advantages of this model is its flexibility in data input which makes it a suitable choice for predicting landfill gas emissions. The LandGEM-v302 model is recognized as a suitable tool for predicting LFG emissions from waste generated in landfills. LandGEM-v302 estimates the quantity and composition of gas generated over time due to the degradation of organic matter in landfills (Chandra & Ganguly, 2023). Following are the similarities of landgem-v302 *(The Landfill Methane Outreach Programam*, 2020):

$$QCH4=\sum_{i=1}^{n}\sum_{j=0.1}^{1} kL0 \left(\frac{M_i}{10}\right) e^{-kt} \quad (1)$$

With:
QCH4 = CH4 emission level
n = total time of the waste accumulation process
k = constant of Landfill gas emissions
L0 = methane gas production potential from the available waste volume
ti = length of time for waste accumulation
Mi = mass of waste / weight of waste
j = 0.1 time per year

Meanwhile, the electric power capacity produced by methane gas can be calculated using the following equation:

$$\text{Total electricity} = \text{Methane gas x } 11.17 \text{ kWh} \quad (2)$$

The heat potential of 1 kg of methane gas is equivalent to 6.13 x 107J, and 1 kWh of electricity is equivalent to 3.6 x 106J, so 1 m3 of methane gas is equivalent to 11.17 kWh (Kusuma et al., 2020).

## Renewable Energy Economic Value Feasibility

To make investment decisions on waste-based renewable energy, it is necessary to take into account both system costs and operational costs. The parameters used to calculate the feasibility of economic value are investment feasibility, namely (Newnan et al., 2012):

*Net Present Value* (NPV)

$$NPV = \sum_{t=0}^{n} \frac{CIF_t}{(1+k)^t} - COF \quad (3)$$

Information:
k = discount rate used
COF = cash outflow / investment
CIFt = cash in flow in period t
n = the last period of expected cash flow

*Internal Rate of Return* (IRR)

$$IRR = i1 + \left(\frac{NPV_1}{NPV_1 - NPV_2}\right) x\ (i_2 - i_1) \quad (4)$$

Information:
i1 = Discount rate which results in NPV+
i2 = The discount rate that yields the NPV-
NPV1 = Net Present Value is positive
NPV2 = Net Present Value is negative

*Benefit/ Cost Ratio* (B/CR)

$$BCRT = \frac{\sum_{1}^{n} CIF_t}{invesment\ cost} \quad (5)$$

Information:
Q: time
CIF: cash in flow

*Payback Period* (PP)

$$PP = \left(\frac{invesment\ cost}{annual\ cif}\right) \quad (6)$$

Information:
*Investment costs*: investment costs
*Annual cif: cash in flow of year*

## RESULT AND DISCUSSION

### Conditions of Waste Management in Palopo City

Palopo City is one of three autonomous regions with municipality status in South Sulawesi. The geographical location of Palopo City is in the far north of Makassar City, with an area of 247.5 km2. Along with the growth in the population of Palopo City, waste production is also increasing. Data on the number of residents and the total volume of waste in the city of Palopo can be seen in table 1.

**Table 1. Data on population and waste volume for 2018-2022**

| Year | Number of Population (Person/Year) | Waste Volume (Tons/Year) |
|---|---|---|
| 2018 | 180,678 | 16,568.65 |
| 2019 | 184,614 | 18,792.83 |
| 2020 | 184,681 | 19137.64 |
| 2021 | 187,331 | 18,279.96 |
| 2022 | 190,687 | 17,651,967 |

Palopo city waste processing, starting from collecting and sorting waste in households, offices, shops, and hotels, which is then collected by collectors (using garbage carts) at Temporary Waste Disposal Sites (TPS) in each village. Garbage from the TPS is then transported by a waste transportation system using a fleet of special garbage trucks, to be disposed of at the Final Disposal Site (TPA).

UPT TPA Mancani processes and processes the waste transported by the UPT Cleaning fleet, in carrying out waste processing and processing UPT Mancani does it using the composting and controlled landfill methods. The total area of Mancani Landfill is 11 Ha2, has 4 landfill zones, but only zone 4 is still active today, equipped with a simple waste water management system and methane gas utilization system.

UPT TPA Mancani, Palopo city, began managing waste with a landfill control system since 2014 and has 4 disposal zones, 3 of which are no longer active. The area of the control landfill is 37,370 m2 or length, L: 202 m in width, W: 185. The control landfill management system is equipped with a leachate pond with an area of 816 m2, L: 68 m, L: 12 m. TPA Mancani also utilizes methane gas produced from the landfill control system. Currently, only zone 4 of the active landfill control is active, according to TPA Mancani officials, the high waste generation in zone 4 currently reaches 12 m. The capacity of a control landfill can be measured using the following formula (Allo & Widjasena, 2019):

$$\text{Capacity} = p x l x t x \text{ level of waste compaction} \quad (7)$$

The minimum waste compaction level is 600 Kg/m3 based on Permen PU No. 13 of 2013. so:

Capacity = 202 x 185 x 12 x 600 Kg/m3 = 262,064,000 Kg

Capacity = 269,064 tons

**Renewable Energy Potential of the Mancani Palopo TPA Landfill**

As with other power generation technologies, the main source of raw material for PLTSa to produce electricity is waste. Thus, to calculate the potential for electrical energy that can be generated in the future based on projected data on the population and total volume of waste in the city of Palopo. One method that can be used to perform data projections is the geometric method with the following equation (Hadisbroto et al., 2021):

Population data projection:

$$Pn = Po(1 + r)dn \quad (8)$$

Pn: future population

Po: total population at the end of the previous year

r: natural population growth rate in percent

dn: calculated time difference

Data projection of the amount of waste volume:

$$PJTS = (JP \times ETS)/1000 \text{ and } TTS = PJTS \times 365 \text{ days} \quad (9)$$

PJTS: potential amount of waste generation (tonnes/day),

JP: total population,

ETS: estimated waste generation per person 0.5 kg (medium and small cities),

TTS: waste generation target per year (tonnes/year)

By using these equations and the data in table 1, the projection data is obtained as follows:

**Table 2. Projection data and accumulation of waste volume**

| Year | Number of Population (Person) | Total Waste Generation (Tons) | Accumulated Waste Volume (Tons) |
|---|---|---|---|
| 2024 | 197,008 | 35,953.89 | 35,953.89 |
| 2025 | 200,246 | 36,544.91 | 72,498.80 |
| 2026 | 203,538 | 37145.64 | 109,644.45 |
| 2027 | 206,884 | 37,756.25 | 147,400.70 |
| 2028 | 210,284 | 38,376.90 | 185,777.60 |

| Year | Number of Population (Person) | Total Waste Generation (Tons) | Accumulated Waste Volume (Tons) |
|---|---|---|---|
| 2029 | 213,741 | 39007.75 | 224,785.34 |
| 2030 | 217,255 | 39,648.96 | 264,434.31 |

The calculation of the population projection shows that the population growth value for the city of Palopo for 2016-2022 is 2%, so that the population projection data for 2024-2030 also shows the same trend. While the results of the calculation of the projected waste volume also show an increasing trend, this is because in the projection the only influencing factor is the population. It is known that the waste receiving capacity of the Mancani landfill system is 269,064 tons. If it is assumed that the Municipal Government of Palopo will make a landfill system with the same specifications as the previous one and start operating in 2024, it is estimated that the Mancani TPA will reach over capacity in 2030 based on projected waste volume.

Calculating landfill gas uses LandGem-v302 tools based on Microsoft excel, with default parameters. The waste volume data that is substituted into the LandGem-v302 tool is the amount of waste generation for the 2024-2030 period.

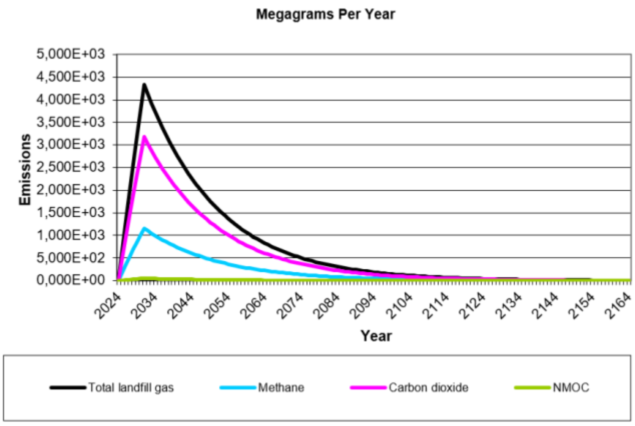


**Figure 1. Mancani TPA Landfill Gas Production**

The waste received in 2024 will only produce landfill gas and methane gas in 2025 of 543,344.56 m3/year of landfill gas and 271,672.28 m3/year of methane gas. From 2025 the production of landfill gas and methane gas will increase because the volume of waste received by the TPA will also increase to peak production in 2031 with landfill gas production reaching 3,468,037.17 m3/year and methane gas 1,734,018.58 m3/year . Even though they will no longer receive waste in 2031, the production of landfill gas and methane gas will continue for 80 years, but will experience a decrease in production from 2032-2110. m3/year.

Waste-based renewable energy is produced by methane gas produced from waste generation in landfills, every 1 m3 of methane gas is equivalent to 11.17 kWh (Kusuma et al., 2020). As for the revenue from the sale of renewable energy, it is assumed that all the energy produced will be sold. Referring to Permen of ESDM No. 44 of 2015 concerning the purchase of electricity by PLN from municipal waste-based power plants, the purchase of electricity for medium-voltage landfills is IDR 2,491/kWh. So that the obtained renewable energy from methane gas is as follows:

**Table 3. Projection data and accumulation of waste volume**

| Year | methane gas m3/year | Energy (kWh) 11.17 kWh | Revenue (IDR) IDR 2,491 |
|---|---|---|---|
| 2024 | 0.00 | 0.00 | IDR 0 |
| 2025 | 271,672.28 | 3,034,579.34 | IDR 7,559,137,142 |
| 2026 | 534,560.75 | 5,971,043.57 | IDR 14,873,869,526 |
| 2027 | 789,167.22 | 8,814,997.79 | IDR 21,958,159,505 |
| 2028 | 1,035,970.21 | 11,571,787.26 | IDR 28,825,322,055 |
| 2029 | 1,275,426.16 | 14,246,510.20 | IDR 35,488,056,902 |
| 2030 | 1,507,970.47 | 16,844,030.14 | IDR 41,958,479,089 |
| 2031 | 1,734,018.58 | 19,368,987.58 | IDR 48,248,148,060 |
| 2032 | 1,649,449.50 | 18,424,350.91 | IDR 45,895,058,113 |
| 2033 | 1,569,004.90 | 17,525,784.71 | IDR 43,656,729,716 |
| 2034 | 1,492,483.63 | 16,671,042.10 | IDR 41,527,565,883 |
| 2035 | 1,419,694.34 | 15,857,985.79 | IDR 39,502,242,596 |
| 2036 | 1,350,455.03 | 15,084,582.69 | IDR 37,575,695,491 |
| 2037 | 1,284,592.56 | 14,348,898.91 | IDR 35,743,107,197 |
| 2038 | 1,221,942.24 | 13,649,094.86 | IDR 33,999,895,289 |
| 2039 | 1,162,347.42 | 12,983,420.65 | IDR 32,341,700,829 |
| 2040 | 1,105,659.06 | 12,350,211.75 | IDR 30,764,377,467 |
| 2041 | 1,051,735.44 | 11,747,884.81 | IDR 29,263,981,073 |
| 2042 | 1,000,441.69 | 11,174,933.71 | IDR 27,836,759,875 |
| 2043 | 951,649.58 | 10,629,925.76 | IDR 26,479,145,075 |
| 2044 | 905,237.08 | 10,111,498.17 | IDR 25,187,741,931 |
| 2045 | 861088.15 | 9,618,354.58 | IDR 23,959,321,262 |
| 2046 | 819,092.38 | 9,149,261.89 | IDR 22,790,811,375 |
| 2047 | 779,144.77 | 8,703,047.13 | IDR 21,679,290,388 |
| 2048 | 741,145.43 | 8,278,594.51 | IDR 20,621,978,920 |
| 2049 | 704,999.35 | 7,874,842.69 | IDR 19,616,233,140 |
| 2050 | 670,616.12 | 7,490,782.08 | IDR 18,659,538,161 |
| 2051 | 637,909.79 | 7,125,452.33 | IDR 17,749,501,746 |
| 2052 | 606,798.56 | 6,777,939.92 | IDR 16,883,848,331 |
| 2053 | 577,204.65 | 6,447,375.89 | IDR 16,060,413,331 |
| 2054 | 549,054.04 | 6,132,933.65 | IDR 15,277,137,730 |
| 2055 | 522,276.36 | 5,833,826.95 | IDR 14,532,062,931 |
| 2056 | 496,804.64 | 5,549,307.85 | IDR 13,823,325,859 |
| 2057 | 472575.19 | 5,278,664.91 | IDR 13,149,154,301 |
| 2058 | 449,527.43 | 5,021,221.39 | IDR 12,507,862,479 |
| 2059 | 427,603.72 | 4,776,333.53 | IDR 11,897,846,827 |
| 2060 | 406,749.24 | 4,543,389.00 | IDR 11,317,581,990 |
| 2061 | 386,911.84 | 4,321,805.30 | IDR 10,765,617,004 |
| 2062 | 368,041.93 | 4,111,028.37 | IDR 10,240,571,667 |
| 2063 | 350,092.31 | 3,910,531.15 | IDR 9,741,133,093 |
| 2064 | 333018.11 | 3,719,812.29 | IDR 9,266,052,426 |
| 2065 | 316,776.63 | 3,538,394.91 | IDR 8,814,141,717 |
| 2066 | 301,327.25 | 3,365,825.35 | IDR 8,384,270,953 |
| 2067 | 286,631.34 | 3,201,672.11 | IDR 7,975,365,233 |
| 2068 | 272,652.17 | 3,045,524.72 | IDR 7,586,402,081 |
| 2069 | 259,354.77 | 2,896,992.73 | IDR 7,216,408,885 |
| 2070 | 246,705.88 | 2,755,704.73 | IDR 6,864,460,471 |
| 2071 | 234,673.90 | 2,621,307.42 | IDR 6,529,676,783 |
| 2072 | 223,228.72 | 2,493,464.75 | IDR 6,211,220,689 |
| 2073 | 212,341.72 | 2,371,857.04 | IDR 5,908,295,881 |
| 2074 | 201,985.69 | 2,256,180.21 | IDR 5,620,144,891 |
| 2075 | 192,134.74 | 2,146,145.00 | IDR 5,346,047,190 |
| 2076 | 182,764.21 | 2,041,476.27 | IDR 5,085,317,392 |
| 2077 | 173,850.70 | 1,941,912.30 | IDR 4,837,303,536 |
| 2078 | 165,371.90 | 1,847,204.12 | IDR 4,601,385,459 |
| 2079 | 157,306.62 | 1,757,114.91 | IDR 4,376,973,242 |
| 2080 | 149,634.68 | 1,671,419.41 | IDR 4,163,505,738 |
| 2081 | 142,336.91 | 1,589,903.32 | IDR 3,960,449,167 |

| Year | methane gas m3/year | Energy (kWh) 11.17 kWh | Revenue (IDR) IDR 2,491 |
|---|---|---|---|
| 2082 | 135,395.06 | 1,512,362.82 | IDR 3,767,295,782 |
| 2083 | 128,791.76 | 1,438,604.01 | IDR 3,583,562,599 |
| 2084 | 122,510.52 | 1,368,442.47 | IDR 3,408,790,188 |
| 2085 | 116,535.61 | 1,301,702.74 | IDR 3,242,541,529 |
| 2086 | 110852.10 | 1,238,217.95 | IDR 3,084,400,913 |
| 2087 | 105,445.78 | 1,177,829.35 | IDR 2,933,972,905 |
| 2088 | 100303.13 | 1,120,385.93 | IDR 2,790,881,358 |
| 2089 | 95,411.29 | 1,065,744.07 | IDR 2,654,768,468 |
| 2090 | 90758.02 | 1,013,767.11 | IDR 2,525,293,882 |
| 2091 | 86,331.70 | 964,325.11 | IDR 2,402,133,846 |
| 2092 | 82121.25 | 917,294.42 | IDR 2,284,980,396 |
| 2093 | 78,116.15 | 872,557.44 | IDR 2,173,540,587 |
| 2094 | 74,306.38 | 830,002.31 | IDR 2,067,535,762 |
| 2095 | 70,682.42 | 789,522.62 | IDR 1,966,700,853 |
| 2096 | 67,235.20 | 751017.15 | IDR 1,870,783,720 |
| 2097 | 63,956.10 | 714,389.61 | IDR 1,779,544,522 |
| 2098 | 60,836.92 | 679,548.42 | IDR 1,692,755,111 |
| 2099 | 57,869.87 | 646,406.45 | IDR 1,610,198,470 |
| 2100 | 55,047.52 | 614,880.84 | IDR 1,531,668,164 |
| 2101 | 52,362.82 | 584,892.74 | IDR 1,456,967,826 |
| 2102 | 49,809.06 | 556,367.19 | IDR 1,385,910,667 |
| 2103 | 47,379.84 | 529,232.84 | IDR 1,318,319,006 |
| 2104 | 45069.10 | 503,421.85 | IDR 1,254,023,830 |
| 2105 | 42,871.05 | 478,869.68 | IDR 1,192,864,366 |
| 2106 | 40,780.21 | 455,514.93 | IDR 1,134,687,684 |
| 2107 | 38,791.33 | 433,299.20 | IDR 1,079,348,313 |
| 2108 | 36,899.46 | 412,166.95 | IDR 1,026,707,874 |
| 2109 | 35,099.85 | 392,065.33 | IDR 976,634,740 |
| 2110 | 33,388.01 | 372,944.08 | IDR 929,003,702 |

The results of the calculation of renewable energy show that waste-based renewable energy production is very dependent on the amount of methane gas production. This means that the greater the landfill capacity to receive waste and also the large volume of waste has the potential to produce methane gas which is useful for producing waste-based renewable energy.

## Feasibility of Economic Value of Renewable Energy Landfill Gas

In accordance with the projected waste volume data for 2024-2030, the WTE technology used is a technology with a waste receiving capacity of 100 tons/day. Based on *US Environmental Protection Agency*, (2007) the total cost of WTE technology based on landfill gas is USD 10,594,350 or equivalent to IDR 148,320,900,000. The details of costs for landfill technology are as follows:

**Table 3. Cost Details of Landfill Gas Technology**

| Component | Cost (USD) |
|---|---|
| Biomass prep-yard | 2,639,700 |
| gasification section | 1,837,000 |
| generation/ heat recovery equipment | 4,740,650 |
| prep-yard O&M | 400,000 |
| Gasifer O&M | 502,000 |
| generator/ heat recovery equipment O&M | 475,000 |
| Total Cost | 10,594,350 |

Assessment of the economic feasibility of renewable energy based on landfill gas waste systems is carried out by calculating the investment criteria, namely NPV, IRR, BCR, PP with ms tools. excel. The results of the calculation and evaluation of the economic feasibility of the waste-based renewable energy potential of the Mancani Palopo TPA landfill gas system can be seen in the following table:

**Table 4. Evaluation of Economic Feasibility of Renewable Energy Landfill Gas**

| Parameter | The calculation results | Criteria | Conclusion |
|---|---|---|---|
| NPV | IDR 135,813,108,537 | NPV > 0 | Worthy |
| IRR | 19% | IRR>15% | Worthy |
| BRC | 1.92 | BRC>1 | Worthy |
| pp | 8.09Year | PP < 87 years | Worthy |

The results of the economic value feasibility test obtained an NPV value with a 10% discount factor of IDR 135,813,108,537, so it can be categorized as feasible because the NPV value is greater than (>) zero (0). The IRR value with a factor discount of 15% is 19%, which means that the technological capability of WTE landfill gas is still capable of making a return on capital even with an interest rate of 19% and is declared feasible because the IRR value is greater than (>) the factor discount (15%). As for the value of the benefits, namely the BRC, a value of 1.92 means that the landfill gas renewable energy project has greater benefits than the capital issued and stated because the BRC value is greater than (>) one (1). The PP value was 8.9, meaning that the potential for renewable energy landfill gas projects is predicted to be restored within 8.9 years.

## CONCLUSION

The increase in waste volume in the 2024-2030 projection data is a potential for renewable energy power plants that utilize methane gas produced by waste in landfill waste management systems. LandgGem-v302 test results using projected data for 2024-2030 show an increase and decrease in landfill gas and methane gas production which is proportional to the increase in the amount of waste volume. These increases and decreases also affect the production of the resulting renewable energy. Meanwhile, the results of the economic value test also show that renewable energy from methane gas in landfill systems meets the four investment feasibility criteria.

## REFERENCES

Allo, S. L., & Widjasena, H. (2019). Studi Potensi Pembangkit Listrik Tenaga Sampah (Pltsa) Pada Tempat Pembuangan Akhir (Tpa) Makbon Kota Sorong. Jurnal Elektro Luceat, 5(2).

Badan Pusat Statistik. (2020). Konsumsi Listrik Per Kapita (Mwh/Kapita). Https://Www.Bps.Go.Id.

Chand Malav, L., Yadav, K. K., Gupta, N., Kumar, S., Sharma, G. K., Krishnan, S., Rezania, S., Kamyab, H., Pham, Q. B., Yadav, S., Bhattacharyya, S., Yadav, V. K., & Bach, Q. V. (2020). A Review On Municipal Solid Waste As A Renewable Source For Waste-To-Energy Project In India: Current

Practices, Challenges, And Future Opportunities. Journal Of Cleaner Production, 277, 123227. Https://Doi.Org/10.1016/J.Jclepro.2020.123227

Chandra, S., & Ganguly, R. (2023). Assessment Of Landfill Gases By Landgem And Energy Recovery Potential From Municipal Solid Waste Of Kanpur City, India. Heliyon, 9(4), E15187. Https://Doi.Org/10.1016/J.Heliyon.2023.E15187

Choden, Y., Tenzin, T., K., K., Norbu, K., Wangmo, S., & Zangmo, P. (2021). Estimation Of Energy Content In Municipal Solid Waste Of Bhutan And Its Potential As Alternate Powers Source. Environment Conservation Journal, 22(1&2), 27–33. Https://Doi.Org/10.36953/Ecj.2021.221205

Cudjoe, D., & Han, M. S. (2021). Economic Feasibility And Environmental Impact Analysis Of Landfill Gas To Energy Technology In African Urban Areas. Journal Of Cleaner Production, 284, 125437. Https://Doi.Org/10.1016/J.Jclepro.2020.125437

Cudjoe, D., Han, M. S., & Chen, W. (2021). Power Generation From Municipal Solid Waste Landfilled In The Beijing-Tianjin-Hebei Region. Energy, 217, 119393. Https://Doi.Org/10.1016/J.Energy.2020.119393

Darmawan, A., Budhi Soesilo, T. E., & Wahyono, S. (2020). Model Optimasi Pengelolaan Sampah Di Tpa (Suatu Studi Di Tempat Pengolahan Sampah Terpadu Bantargebang). Jurnal Pendidikan Lingkungan Dan Pembanganan Berkelanjutan, 21(02). Https://Doi.Org/10.21009/Plpb.212.02

Efrizal, W. (2022). Dampak Cemaran Dioksin Bagi Keadaan Gizi Dan Kesehatan: Literature Review. Jurnal Kesehatan Lingkungan: Jurnal Dan Aplikasi Teknik Kesehatan Lingkungan, 19(1), 23–30. Https://Doi.Org/10.31964/Jkl.V19i1.400

Esdm.Go.Id. (2020). Semester I 2022, Realisasi Batubara Untuk Kelistrikan Capai 72,94 Juta Ton. Https://Www.Esdm.Go.Id.

Esye, Y., & Iswal, G. S. (2021). Analisis Pembangkit Listrik Tenaga Sampah Dengan Metode Sanitary Landfill Di Bantargebang. Jurnal Sains & Teknologi Fakultas Teknik Universitas Darma Persada, Xi(2).

Hadisbroto, T., Riani, D., & Laufried. (2021). Analisis Prediksi Timbulan Sampah Di Kecamatan Jekan Raya. Jurnal Teknika: Jurnal Teoritis Dan Terapan Bidang Keteknikan, 4(2), 100–108. Https://Doi.Org/10.52868/Jt.V4i2.2722

Huda, T., Preccilia Amor, A., & Priyanto Kusuma, Y. T. (2019). Studi Perencanaan Pembangkit Listrik Tenaga Sampah Pada Tpa Sambutan Kota Samarinda. Specta Journal Of Technology, 3(2).

Ishari, M. (2022). Sampah Berserakan! Kurangnya Kesadaran Masyarakat, Kinerja Pemerintah Belum Maksimal. Https://Www.Atmago.Com/.

Kementerian Esdm. (2023). Pemerintah Optimistis Ebt 23% Tahun 2025 Tercapai. Esdm.Go.Id.

Khrisna Mukti, K. B., Natsir, A., & Muljono, A. B. (2022). Kajian Teknis Dan Ekonomi Pembangkit Listrik Tenaga Sampah (Pltsa) Menggunakan Perangkat Lunak Landgem Tpa Kebon Kongok Gerung Lombok Barat. Dielektrika - Departement Of Electric Engineering Universitas Mataram, 9(1).

Komisi Iv. (2022). Ditjen Pslb3 Klhk Didesak Miliki Langkah Terukur Tangani Volume Sampah. Https://Www.Dpr.Go.Id.

Kusuma, A. V., Barokatun, H., & Slamet. (2020). Forecasting Potensi Energi Gas Metana Menggunakan Pembangkit Listrik Tenaga Sampah (Pltsa) Pada Tpa Manggar Kota Balikpapan. Journal Of Electrical Electronic Control And Automotive Engineering (Jeecae), 5(2).

Maha, I. K., & Susilawati. (2023). Dampak Pencemaran Lingkungan Terhadap Kesehatan. Zahra: Journal Of Health And Medical Research, 3(4), 1–5.

Muttar, M., Hamzah, D. R., Syam, M. I., Alamsyah, A., & Utaminingsih, N. (2021). Dampak Pembangunan Pembangkit Listrik Tenaga Uap Di Kabupaten Jeneponto. Vox Populi, 4(1). Https://Doi.Org/10.24252/Vp.V4i1.21838

Qodriyatun, S. N. (2021). Pembangkit Listrik Tenaga Sampah: Antara Permasalahan Lingkungan Dan Percepatan Pembangunan Energi Terbarukan. Aspirasi: Jurnal Masalah-Masalah Sosial, 12(1), 63–84. Https://Doi.Org/10.46807/Aspirasi.V12i1.2093

Ramprasad, C., Teja, H. C., Gowtham, V., & Vikas, V. (2022). Quantification Of Landfill Gas Emissions And Energy Production Potential In Tirupati Municipal Solid Waste Disposal Site By Landgem Mathematical Model. Methodsx, 9, 101869. Https://Doi.Org/10.1016/J.Mex.2022.101869

Romy, M., Safitri, I. K., Aggistri, Z. S., & F, M. I. (2023). Analisa Potensi Pembangkit Limbah Menjadi Energi Pada Tpa Pembuangan Limbah Di Indonesia Menuju Sdgs 2030. Jurnal Socia Logica, 3(1), 1–11.

Sistem Informasi Pengelolaan Sampah Nasional. (2023). Data Timbulan Sampah Nasional. Https://Sipsn.Menlhk.Go.Id.

Supriatna, J. (2021). Pengelolaan Lingkungan Berkelanjutan. Yayasan Pustaka Obor Indonesia, Jakarta.

Surma, U., Natio, A., Harahap, S., & Firman, L. O. M. (2020). Analisa Pemanfaatan Sampah Perkotaan Untuk Pembangkit Listrik Di Tpa Ciniru Kabupaten Kuningan. Teknobiz: Jurnal Ilmiah Program Studi Magister Teknik Mesin, 10(1).

Syukri, M., & Jelita, M. (2023). Analisis Teknis Dan Ekonomis Pemanfaatan Sampah Organik Sebagai Pltsa Di Tpa Tanjung Belit. Briliant: Juenla Riiset Dan Konseptual, 8(1), 511–526.

The Landfill Methane Outreach Program. (2020). The Lfg Energy Project Development Handbook. In Https://Www.Epa.Gov/.

Thoengsal, J., & Tumpu, M. (2022). Ideal Factor Analysis Of Implementation Management Due To Waste Material Of Building Construction Materials On Contractor Projects In Indonesia. Eduvest-Journal Of Universal Studies, 2(6), 1–81.

U. S. Environmental Protection Agency. (2007). Biomass Combined Heat And Power Catalog Of Technologies. In Https://Www.Epa.Gov/.

Utoyo, E. B., & Sudarti, S. (2022). The Potensi Pembangkit Listrik Tenaga Sampah (Pltsa) Sebagai Solusi Permasalahan Lingkungan Dan Sosial Di Indonesia. Cermin: Jurnal Penelitian, 6(2), 337. Https://Doi.Org/10.36841/Cermin_Unars.V6i2.1727